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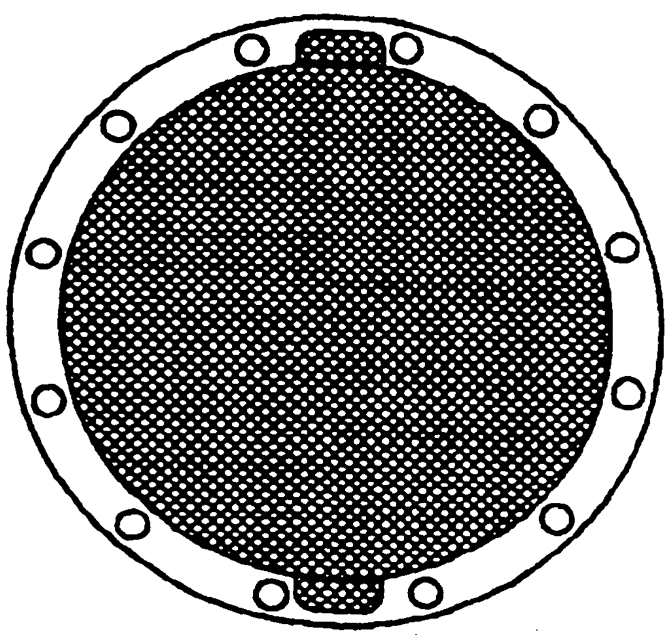
(54) Title: INTEGRAL SCREEN/FRAME ASSEMBLY FOR AN ELECTROCHEMICAL CELL

(57) Abstract

An integral screen/frame assembly for use in an electrochemical cell (1) for supporting and facilitating the hydration of a solid membrane (8). The screen/frame assembly is comprised of planar screen layers (75) having the frame (70) disposed about the periphery of those layers such that the frame bonds the layers together.



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INTEGRAL SCREEN/FRAME ASSEMBLY FOR AN ELECTROCHEMICAL CELL

TECHNICAL FIELD

The present invention relates generally to electrochemical cells, and especially relates to an electrochemical cell having an integral screen/frame assembly and/or a screen pack with a porous woven layer.

BACKGROUND OF THE INVENTION

Electrochemical cells are energy conversion devices, usually classified as either electrolysis cells or fuel cells, including electrolysis cells having a hydrogen water feed. A proton exchange membrane electrolysis cell functions as a hydrogen generator by electrolytically decomposing water to produce hydrogen and oxygen gases. Referring to FIGURE 1, in a typical single anode feed water electrolysis cell 101, process water 102 is reacted at oxygen electrode (anode) 103 to form oxygen gas 104, electrons, and hydrogen ions (protons) 105. The reaction is created by the positive terminal of a power source 106 electrically connected to anode 103 and the negative terminal of a power source 106 electrically connected to anode 103 and the negative terminal of a power source 106 connected to hydrogen electrode (cathode) 107. The oxygen gas 104 and a portion of the process water 102' exit cell 101, while protons 105 and water 102"

migrate across proton exchange membrane 108 to cathode 107 where hydrogen gas 109, is formed.

The typical electrochemical cell includes a number of individual cells arranged in a stack with fluid, typically water, forced through the cells at high pressures. The cells within the stack are sequentially arranged including a cathode electrode, a proton exchange membrane, and an anode electrode. The cathode/membrane/anode assemblies (hereinafter "membrane and electrode assembly") are supported on either side by packs of screen or expanded metal which are in turn surrounded by cell frames and separator plates to form reaction chambers and to seal fluids therein. The screen packs establish flow fields within the reaction chambers to facilitate fluid movement and membrane hydration, and to provide both mechanical support for the membrane and a means of transporting electrons to and from the electrodes.

As stated above, the screen packs support the membrane assembly. The membrane is typically only about 0.002 – 0.012 inches in thickness, when hydrated, with the electrodes being thin structures (less than about 0.002 inches) of high surface area noble metals pressed or bonded to either side of the membrane and electrically connected to a power source. When properly supported, the membrane serves as a rugged barrier between the hydrogen and oxygen gases. The screen packs, positioned on both sides of the membrane against the electrodes, impart structural integrity to the membrane assembly.

Existing cell frames have a number of drawbacks and disadvantages. For example, current technology uses protector rings to bridge the gap between the cell frame and screen packs. The protector rings, typically positioned about the perimeter of the frame, prevent membrane extrusion and "pinching" between the frame and the screen. Although these protector rings function well in operation, they render assembly of the cell very difficult, often breaking loose, resulting in misalignment and possible damage to the membrane. Specifically, because of their small cross-section, the protector rings tend to slide out of position and as a result often do not cover the gap between the frame and the screen which they are intended to bridge.

What is needed in the art is an improved screen assembly which provides structural integrity and simplified cell assembly while maintaining or improving the cell's mass flow characteristics.

SUMMARY OF THE INVENTION

The present invention relates to an integral screen/frame assembly and to an electrochemical cell stack. The screen/frame integral assembly comprises: one or more screen layers having an interior portion with a porosity; and a frame disposed about the periphery of the screen layers while substantially maintaining the porosity of the interior portion, the frame having fluid conduits disposed therein.

The electrochemical cell stack comprises: an electrolyte membrane having a first gas side and a second gas side; a first gas electrode disposed on the first gas side of the membrane; a second gas electrode disposed on the second gas side of the membrane; and an integral screen/frame assembly disposed adjacent to and in intimate contact with the first gas side, comprising: one or more screen layers having an interior portion with a porosity and having a periphery; and a frame disposed about the periphery of the screen layers while substantially maintaining the porosity of the interior portion, the frame having fluid conduits disposed therein.

The above discussed and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, which are meant to be illustrative, not limiting, and wherein like elements are numbered alike in the several FIGURES:

Figure 1 is a schematic diagram of a prior art electrochemical cell showing an electrochemical reaction.

Figure 2 is a cross sectional view of one embodiment of an electrochemical cell showing the relationship of the cell components.

Figure 3 is a plan view of one embodiment of a screen assembly of the present invention.

Figure 4 is a top view of another embodiment of the integrated frame 1 screen assembly of the present invention.

Figure 5 is an expanded side view of the integrated frame 1 screen assembly of Figure 4.

Figure 6 is an isometric view of one embodiment of a woven mesh of the present invention.

Figure 7 is an isometric view of one embodiment of a screen pack of the present invention employing a woven mesh.

The Figures are meant to further illustrate the present invention and not to limit the scope thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The screen/frame assembly of the present invention comprises multilayers of screens with layers of frame material disposed about the periphery, integral with the screen layer. Essentially, the frame forms a ring around and through the outer edge of the screen layers, bonding the layers together in an integral structure.

The screen layers can be any conventional screen configuration, with the configuration disclosed in commonly assigned U.S. Patent Application Serial No. 09/102,305, to Trent Molter et al., (Attorney Docket No. 97-1801) (hereby incorporated by reference) preferred. The screens should be electrically conductive and have a sufficient open area via perforations, openings between screen strands, or otherwise, to enable substantially unobstructed access of hydrogen, oxygen, and water to and/or from the electrodes. Possible screen materials can be electrically conductive materials, including, but not limited to, metal or metal-ceramic plates or stands in the form of perforated or porous sheets, or a woven mesh, such as niobium, nickel, cobalt, zirconium, titanium, steel (such as stainless), or tantalum, among others, and alloys thereof.

At least some of the screens are preferably planar layers having elongated openings, such as diamond or elliptical shapes, formed by strands. These openings can have a size of up to about 2/0 or greater. However, for operation at a pressure differential of about 400 p.s.i., it is preferred to employ small screen openings to prevent membrane blowout into the screen on the low pressure side of the membrane assembly. In one embodiment, a reduced opening size for at least the first screen layer is employed, with a reduced opening size employed for subsequent screen layers based upon mass flow demands. The actual size of the openings (perforations or holes) is dependent upon the desired mass flow rate and number of screen layers to be

employed. Referring to Figure 3, for a diamond pattern, in an electrolysis cell operating at a 390 psi pressure differential, a diamond size of less than 0.125 inches (3.17 mm) for dimension "b" (width), by less than 0.071 inches (1.80 mm) for dimension "a" is preferred. That is, about 3/0 to about 5/0 is preferred, and a 4/0 screen, which is about 0.077 inches (1.96 mm) by about 0.033 inches (0.838 mm) to about 0.046 inches (1.17 mm) is especially preferred for the screen layer adjacent the electrode. Subsequent layers can also employ small opening sizes or can have an opening size larger than the opening size of the screen layer adjacent the electrode to improve mass flow characteristics.

In another embodiment, one or more layers can be a woven mesh screen (see Figure 6). Although this mesh screen can be disposed anywhere within the screen pack, it is preferably disposed adjacent to and in intimate contact with the membrane and electrode assembly or the first screen layer. In this embodiment, the woven mesh screen provides structural integrity to the membrane. However, due to the hydrophobic nature of the mesh screen, an expanded screen having a relatively hydrophilic nature is preferably disposed between the woven mesh screen and the membrane.

The mesh size of the woven mesh screen is based upon the desired structural integrity requirements for the membrane and the desired gas production rate. For example, as the production pressure increases, the woven mesh size decreases to provide the desired structural integrity, and the current density (and therefore the production rate) is decreased to prevent membrane dehydration. Typically, the woven mesh screen can have a mesh size up to and exceeding about 200 mesh, with about 10 to about 110 mesh preferred, and about 20 to about 80 mesh especially preferred.

The preferred mesh size is determined based upon the relationship between the desired current density, production rate, production pressure, and issues of membrane dehydration. Since the woven mesh provides structural integrity to the membrane, as the production pressure increases, the mesh size preferably decreases (e.g. at a production pressure of about 50 p.s.i. the preferred mesh size is about 20 mesh, while at a production pressure of about 400 p.s.i. the preferred mesh size is about 80 mesh). As the mesh size decreases, however, the transfer characteristics of water to the membrane and oxygen from the membrane are restricted. Consequently, localized membrane dehydration can occur. To avoid membrane dehydration, it is typically preferred to

decrease the current density, thereby decreasing the production rate of oxygen and hydrogen. Therefore, the balance of the desired production rate and membrane structural integrity is weighed against the possibility of membrane dehydration.

Referring to Figure 7, in this embodiment the screen layer disposed between the woven mesh and the electrode has screen openings that are elongated, such as diamond or elliptical shaped. These openings can have a size of about 3/0 to about 5/0, with smaller openings especially preferred for higher pressure differential applications. The screen layer disposed between the woven mesh and the electrode has a thickness up to about 5 mil, with about a 3 mil thickness or less preferred. In contrast, subsequent screen layers (i.e. those disposed on the opposite side of the woven mesh) typically have screen openings up to or exceeding about 7/0, with about 3/0 to about 5/0 generally preferred, and about 4/0 especially preferred, and have a thickness up to about 7 mils or more, with a thickness of about 3 mil to about 5 mil generally employed.

The integral frame can be formed of any material that is compatible with the electrochemical cell environment, is capable of bonding the screen layers together, and preferably, is easily processed. Possible frame materials include, but are not limited to, thermosetting, thermoplastic, and rubber materials, such as polyetherimide, polysulfone, polyethersulfone, and polyarylether ketone (PEEK), Viton® (commercially available from E.I. duPont de Nemours and Company, Wilmington, DE), ethylenepropylenediene monomer, ethylenepropylene rubber, among others, and mixtures thereof, with thermoplastic materials preferred due to ease of manufacture. One example of a useful thermoplastic material is polyetherimide (e.g. Ultem® 1000 commercially available from General Electric Company, Pittsfield, MA).

Production of the screen/frame assembly can be any conventional manner of extruding the frame material into the screen layers accordingly, with actual processing conditions dependent upon the particular material employed. For example, Ultem® resin can be integrated with the screen layers by stacking the screen layers accordingly; placing an Ultem® resin ring above, below, and/or within the screen stack (70, 70'), and heating the stack under pressure to extrude the Ultem® resin through the stack, about the periphery of the screen layers (75, 75') (see Figure 5). In the alternative, multiple thin layers of Ultem® resin can be alternately stacked between the screen layers. Again

the stack is heated under pressure to force the Ultem® resin through the screens, thereby bonding them together to form an integral screen/frame assembly (see Figure 4).

Temperatures and pressures sufficient to extrude the frame through the periphery of the screen and bond the various layers of screen and frame together can be employed. Typically, with a thermoplastic material such as Ultem® resin, for example, temperatures of about 250°F to 500°F at pressures of about 10,000 to 20,000 pounds per square inch (psi) can be used, with temperatures of about 300°F to about 350° F at pressures of about 13,500 psi to about 16,000 psi preferred.

The frame material should have a sufficient overall thickness to enable bonding of all of the screen layers and to attain sufficient electrical contact between the screen layers and the membrane, while preferably not forming a ridge or other extension above the surface layers of the screens. Preferably, the overall frame thickness is approximately equal to the overall screen thickness to establish a uniformity between the frame and screen interface.

In a further preferred embodiment, the frame has the desired manifolds formed therein prior to assembling with the screens. In this embodiment, it is preferred not to over-heat the frame material. Preferably the material is only heated to a temperature which will enable extrusion into the screen, without allowing significant deformation or blockage of the manifolds. Once the extrusion process is complete, the integrated frame/screen assembly is preferably cooled slowly so as to reduce thermal stress. For example, the assembly is cooled from about 350°F to about 90°F or lower over a period of about 15 minutes or more.

Referring now to Figure 2, in operation, process water 2 enters inlet port 25 and a portion of the water is diverted into oxygen screen pack 43. A portion of the water 2 not diverted into screen pack 43, continues along conduit 25 formed by axially aligned holes in the components comprising the stack, and enters subsequent cells in the cell stack (not shown) positioned outside of the cell 1. The portion of process water 2 diverted through screen pack 43 contacts anode 3 where the water electrochemically converts to oxygen gas, protons, and electrons. Oxygen gas, as well as excess water, is exhausted from the cell through porting arrangements similar to those through which water is directed to the anode 3. The generation of gases in the cell, combined with external pressure regulation, produces a large pressure differential between the oxygen

side and the hydrogen side of the cell. This pressure differential forces membrane 8 and cathode 7 against the opposing screen pack. It should be noted that the direction of the pressure differential, i.e., greater or lower pressure on the cathode side, is dependent upon the application requirements of the electrochemical system.

In another embodiment a hydrogen feed cell can be used. A hydrogen feed cell feeds water to the membrane from the hydrogen side of the membrane. As water on the oxygen side electrode is electrochemically broken down into protons and oxygen, the membrane becomes locally less saturated with water. Water from the hydrogen side of the membrane is then wicked or drawn to the oxygen side to the less saturated areas of the membrane, and a constant supply of reactant water to the membrane is thereby established. In this embodiment, factors such as current density and feed pressures are controlled as before to assure membrane integrity.

The screen/frame assembly of the present invention is inexpensive to develop and manufacture for the following reasons, among others, the ability to manufacture using continuous processing; elimination of the requirement for expensive molds; elimination of the need for the protector ring; simplification of cell assembly and reduction of assembly time due to the integration of parts; enhancement of reliability due to reduced handling; and ready automation of the manufacturing process for high volume production with roll sheeting and heated rollers. For example, the screen/frame integral assembly establishes a significantly lower pressure drop across the fluid manifolds (in the order of about 0.10 of the pressure drop of conventional screen frame assembly), provides membrane support of elevated pressure operation (greater than about 1,000 p.s.i.g. (pounds per square inch gauge) and up to or exceeding 2,000 p.s.i.g., with up to about 4,000 p.s.i.g. and greater possible), requires less energy to move fluids, and eliminates the need for mechanical compression compared to conventional systems which employ separate screens and frames.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

Claims:

1. A screen/frame integral assembly, comprising:

one or more screen layers having an interior portion with a porosity and having a periphery; and

a frame disposed about the periphery of said screen layers while substantially maintaining the porosity of said interior portion, said frame having fluid conduits disposed therein.

2. A screen/frame integral assembly as in Claim 1, comprising at least two screen layers, wherein said frame bonds said screen layers together.

3. A screen/frame integral assembly as in Claim 2, wherein said screen layers comprise:

a first screen layer having first openings having a size of about 0.077 inches (1.96 mm) or less by about 0.033 inches (0.838 mm) or less and a thickness of less than about 0.005 inches (0.127 mm), wherein said size and said thickness are interrelated such that the combination of said size and said thickness enable the passage of water and a gas through said first openings; and

at least one subsequent screen layer having second openings, wherein said subsequent screen layer is disposed parallel to and in contact with said first screen layer.

4. A screen/frame integral assembly as in Claim 3, wherein said thickness is about 0.004 inches (0.102 mm) or less.

5. A screen/frame integral assembly as in Claim 3, wherein said thickness is about 0.089 mm or less.

6. A screen/frame integral assembly as in Claim 3, wherein at least a portion of said second openings having a larger size than said first openings size.

7. A screen/frame integral assembly as in Claim 3, wherein at least a portion of said subsequent screen layers have second strands having a second thickness greater than said first thickness.

8. A screen/frame integral assembly as in Claim 7, wherein said first thickness is about half of said second thickness.

9. A screen/frame integral assembly as in Claim 1, wherein said screen layers have first openings which have a substantially elongated, diamond or oval shaped geometry.

10. A screen/frame integral assembly as in Claim 9, wherein said openings in one screen layer are disposed generally orthogonal to said openings in a subsequent screen layer.

11. A screen/frame integral assembly as in Claim 1, wherein frame is thermoplastic, thermosetting, or rubber materials, or mixtures thereof.

12. A screen/frame integral assembly as in Claim 11, wherein said frame is polyetherimide, polysulfone, polyethersulfone, polyarylether ketone, ethylenepropylenediene monomer, ethylenepropylene rubber, or mixtures thereof.

13. A screen/frame integral assembly as in Claim 1, wherein said screen layers comprise at least one woven layer.

14. A screen/frame intergral assembly as in Claim13, wherein said woven layer is disposed between and in intimate contact with two of said screen layers.

15. A screen/frame integral assembly as in Claim 13, wherein said woven layer has a mesh size down to about 300 mesh.

16. A screen/frame integral assembly as in Claim 15, wherein said woven layer has a mesh size down to about 200 mesh.

17. A screen/frame integral assembly as in Claim 16, wherein said woven layer has a mesh size of about 20 to about 80 mesh.

18. An electrochemical cell stack, comprising:
an electrolyte membrane having a first gas side and a second gas side;
a first gas electrode disposed on said first gas side of said membrane;
a second gas electrode disposed on said second gas side of said membrane; and
an integral screen/frame assembly disposed adjacent to and in intimate contact with said first gas electrode, comprising:
one or more screen layers having an interior portion with a porosity and having a periphery; and
a frame disposed about the periphery of said screen layers while substantially maintaining the porosity of said interior portion, said frame having fluid conduits disposed therein.

19. An electrochemical cell stack as in Claim 18, comprising at least two screen layers, wherein said frame bonds said screen layers together.

20. An electrochemical cell stack as in Claim 19, wherein:

said screen/frame assembly has a first screen layer having first openings having a first size of about 0.077 inches (1.96 mm) or less by about 0.033 inches (0.838 mm) or less and a first thickness of less than about 0.005 inches (0.127 mm) and at least one subsequent screen layer having subsequent openings, wherein said subsequent screen layer is disposed parallel to and in contact with said first screen layer and said first size and said first thickness are interrelated such that the combination of said first size and said first thickness enable the passage of water and the first gas through said first openings; and

a second gas screen assembly disposed adjacent to and in contact with said second gas electrode.

21. An electrochemical cell stack as in Claim 20, wherein the electrochemical cell has a pressure differential across said membrane such that a pressure at said first gas side of said membrane is lower than pressure at said second gas side of said membrane.

22. An electrochemical cell stack as in Claim 21, wherein said subsequent openings have a subsequent size and a subsequent thickness, wherein said first thickness is less than said subsequent thickness.

23. An electrochemical cell stack as in Claim 22, wherein said first thickness is about half of said second thickness or less.

24. An electrochemical cell stack as in Claim 20, wherein said first openings and said subsequent openings have a substantially elongated, diamond, or oval shaped geometry.

25. An electrochemical cell stack as in Claim 24, wherein said first openings are disposed generally orthogonal to said subsequent openings.

26. An electrochemical cell as in Claim 20, wherein said first thickness is about 0.0035 inches (0.089 mm) or less.

27. An electrochemical cell stack as in Claim 18, wherein frame is thermoplastic, thermosetting, or rubber materials, or mixtures thereof.

28. An electrochemical cell stack as in Claim 27, wherein said frame is polyetherimide, polysulfone, polyethersulfone, polyarylether ketone, ethylenepropylenediene monomer, ethylenepropylene rubber, or mixtures thereof.

29. An electrochemical cell as in Claim 18, wherein said screen layers comprise at least one woven mesh.

30. An electrochemical cell as in Claim29, wherein said woven mesh is disposed between and in intimate contact with two of said screen layers.

31. An electrochemical cell as in Claim 29, wherein said woven mesh is from about 20 to about 80 mesh.

32. An electrochemical cell as in Claim 27, wherein said screen/frame assembly is capable of providing structural integrity to said electrolyte membrane with a pressure differential across said electrolyte membrane of greater than 400 psi.

33. An electrochemical cell as is Claim 27, wherein the pressure differential across said electrolyte is greater than 1,000 psig.

34. An electrochemical cell screen assembly, comprising one or more screen layers comprising at least one woven layer and having an interior portion with a porosity.

35. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size down to about 300 mesh.

36. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size down to about 200 mesh.

37. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size of about 20 to about 80 mesh.

38. A method for producing hydrogen, comprising:

a. introducing water to a first gas electrode in an electrochemical cell, said electrochemical cell comprising:

i. an electrolyte membrane disposed between the first gas electrode and a second gas electrode; and

ii. an integral screen/frame assembly disposed adjacent to and in intimate contact with said first gas electrode, comprising: one or more screen layers having an interior portion with a porosity and having a periphery; and a frame disposed about the periphery of said screen layers while substantially maintaining the porosity of said interior portion, said frame having fluid conduits disposed therein;

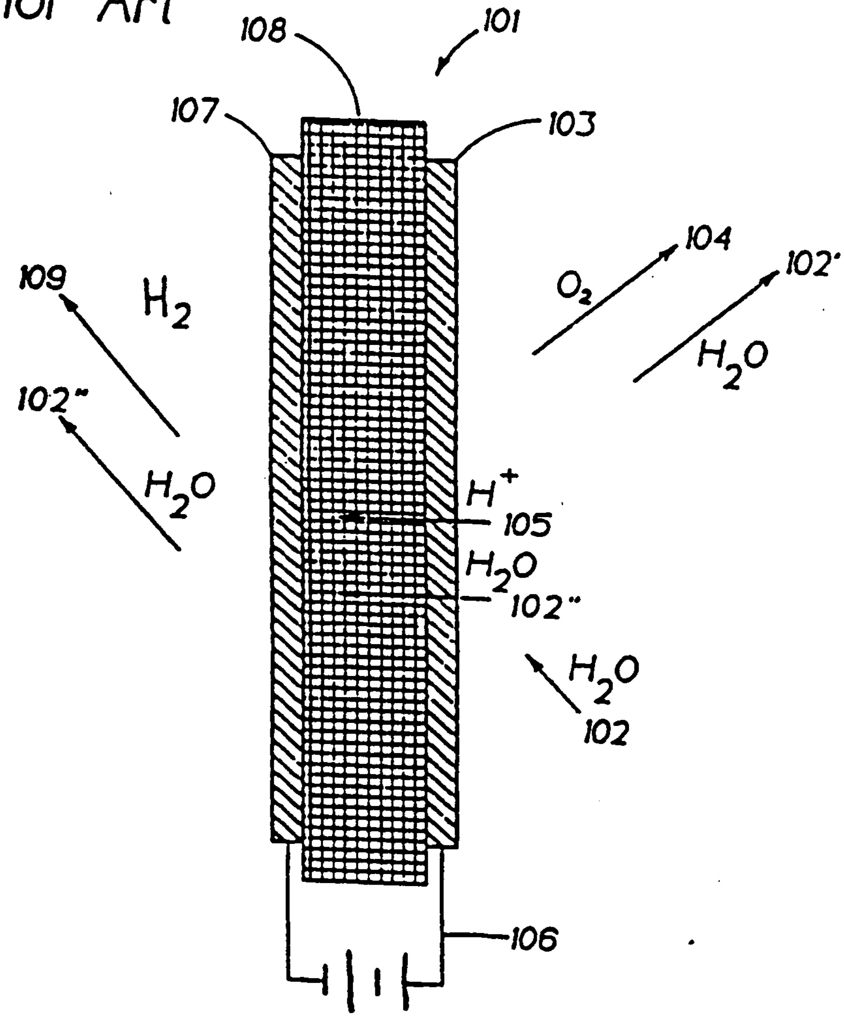
b. forming hydrogen ions, oxygen, and electrodes;

c. passing said hydrogen ions through said electrolyte membrane to said second gas electrode;

d. moving said electrons through an electrical load to said second gas electrode; and

e. combining said hydrogen ions and said electrons to form hydrogen gas.

FIG. 1
Prior Art



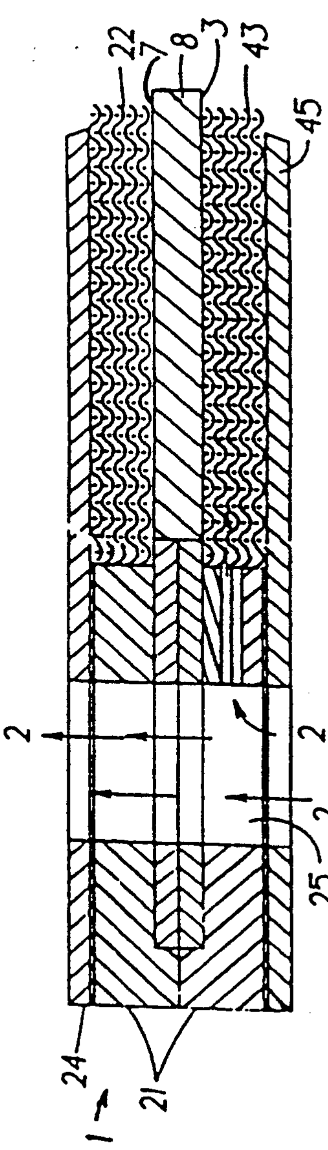


FIG. 2

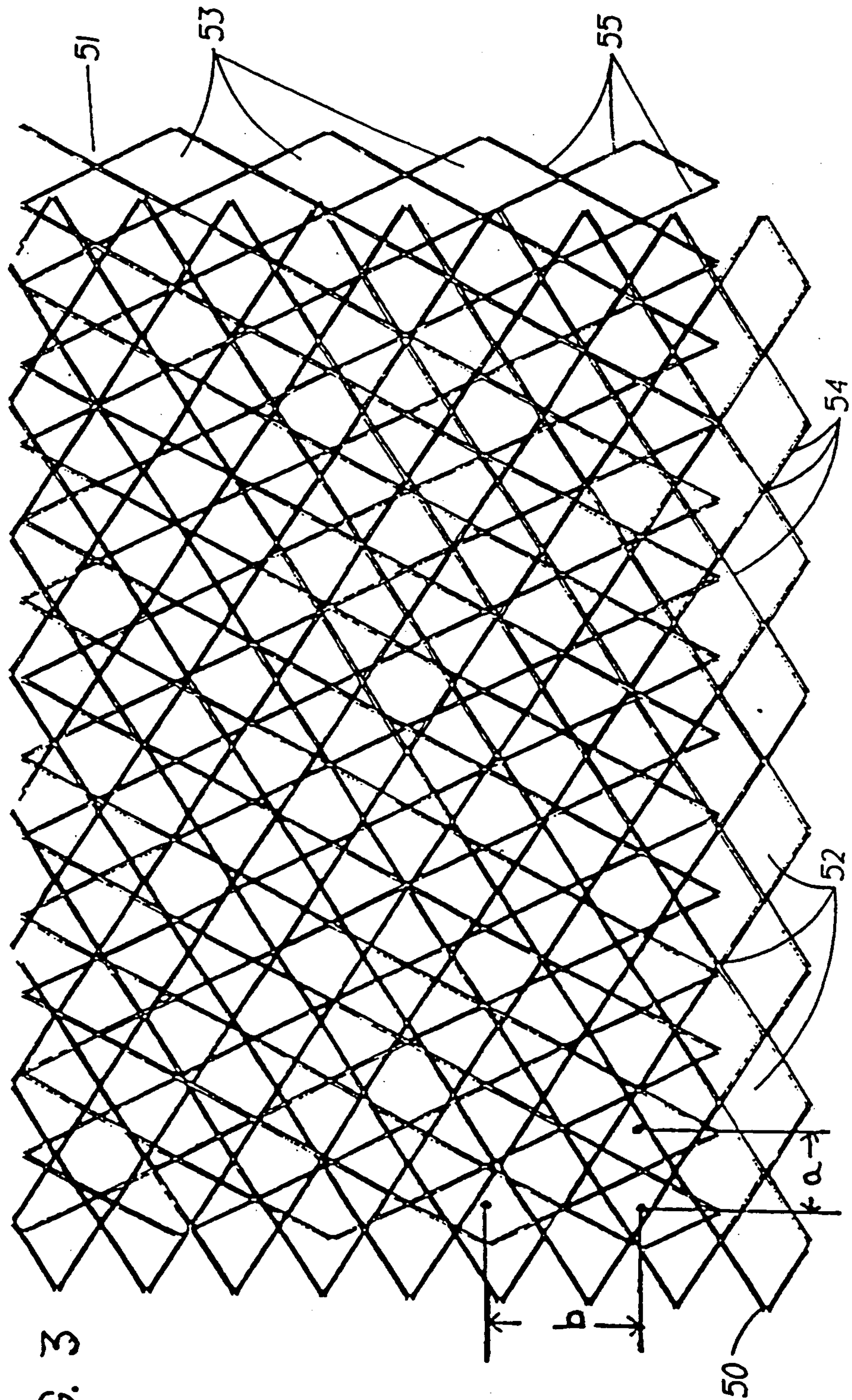


FIG. 3

FIG. 4

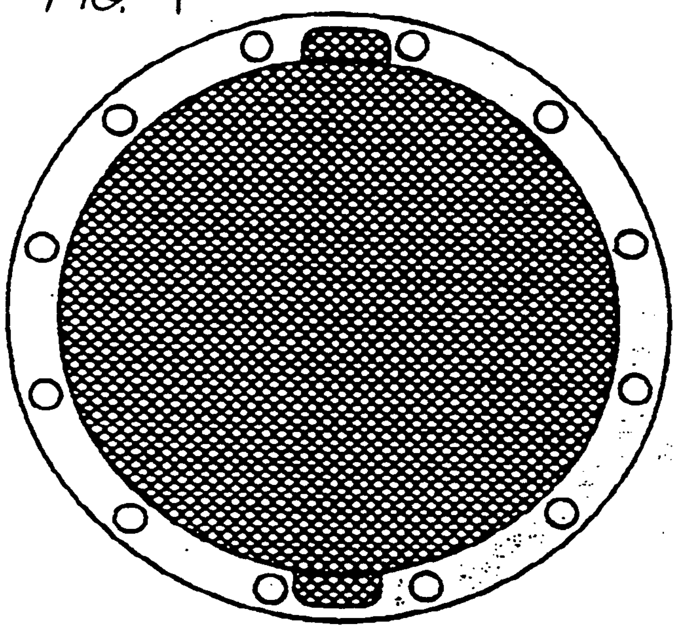


FIG. 5

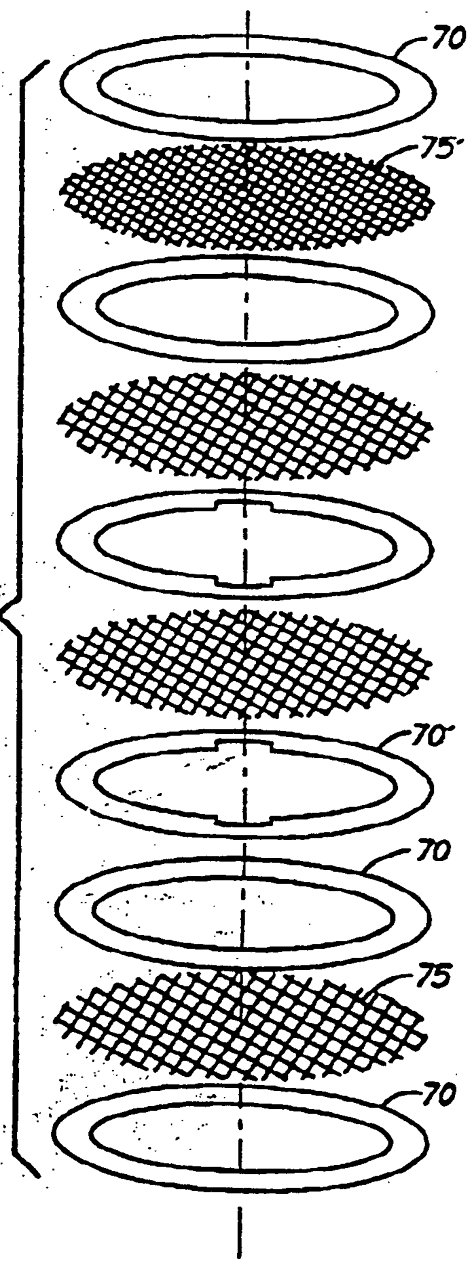


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FIG. 6

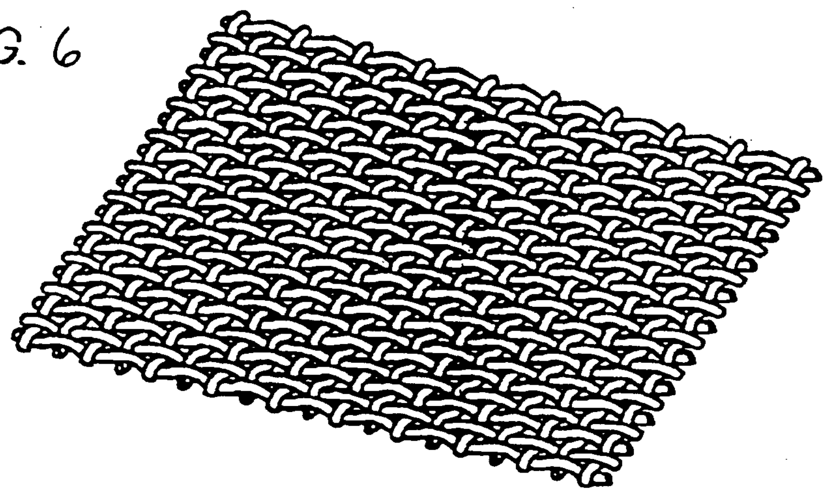
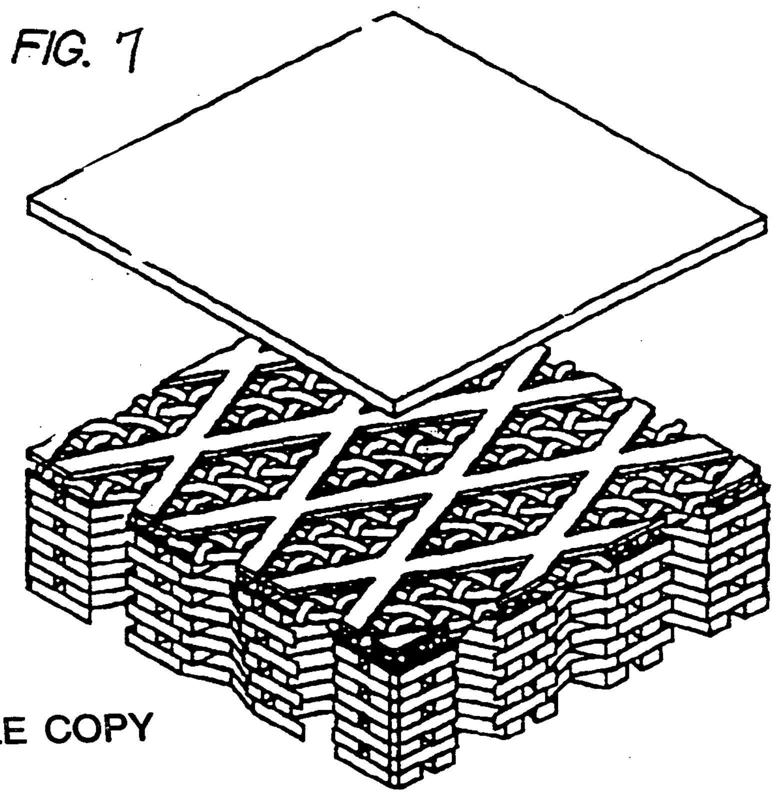


FIG. 7



INTERNATIONAL SEARCH REPORT

Int. .tional Application No
PCT/US 99/30085

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C25B9/00 C25B1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M C25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 13891 A (ZAWODZINSKI CHRISTINE ;UNIV CALIFORNIA (US); WILSON MAHLON S (US)) 2 April 1998 (1998-04-02) page 5, line 9 - line 13 page 7, line 22 -page 8, line 11 page 9, line 27 -page 10, line 17 page 12, line 6 - line 19 page 14, line 1 - line 5 page 14, line 18 - line 21	1,2,6,7, 11,18, 19,22,27
A	figures 2,4	3

X	WO 98 40537 A (UNITED TECHNOLOGIES CORP) 17 September 1998 (1998-09-17) page 6, line 4 - line 22 page 8, line 18 - line 32 page 9, line 3 - line 22 page 9, line 30 -page 10, line 13	1,18,38

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[X] Further documents are listed in the continuation of box C.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 2000	04/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gamez, A

Form PCT/ISA/210 (second sheet) (July 1992)

migrate across proton exchange membrane 108 to cathode 107 where hydrogen gas 109, is formed.

The typical electrochemical cell includes a number of individual cells arranged in a stack with fluid, typically water, forced through the cells at high pressures. The cells within the stack are sequentially arranged including a cathode electrode, a proton exchange membrane, and an anode electrode. The cathode/membrane/anode assemblies (hereinafter "membrane and electrode assembly") are supported on either side by packs of screen or expanded metal which are in turn surrounded by cell frames and separator plates to form reaction chambers and to seal fluids therein. The screen packs establish flow fields within the reaction chambers to facilitate fluid movement and membrane hydration, and to provide both mechanical support for the membrane and a means of transporting electrons to and from the electrodes.

As stated above, the screen packs support the membrane assembly. The membrane is typically only about 0.002 – 0.012 inches in thickness, when hydrated, with the electrodes being thin structures (less than about 0.002 inches) of high surface area noble metals pressed or bonded to either side of the membrane and electrically connected to a power source. When properly supported, the membrane serves as a rugged barrier between the hydrogen and oxygen gases. The screen packs, positioned on both sides of the membrane against the electrodes, impart structural integrity to the membrane assembly.

Existing cell frames have a number of drawbacks and disadvantages. For example, current technology uses protector rings to bridge the gap between the cell frame and screen packs. The protector rings, typically positioned about the perimeter of the frame, prevent membrane extrusion and "pinching" between the frame and the screen. Although these protector rings function well in operation, they render assembly of the cell very difficult, often breaking loose, resulting in misalignment and possible damage to the membrane. Specifically, because of their small cross-section, the protector rings tend to slide out of position and as a result often do not cover the gap between the frame and the screen which they are intended to bridge.

What is needed in the art is an improved screen assembly which provides structural integrity and simplified cell assembly while maintaining or improving the cell's mass flow characteristics.

SUMMARY OF THE INVENTION

The present invention relates to an integral screen/frame assembly and to an electrochemical cell stack. The screen/frame integral assembly comprises: one or more screen layers having an interior portion with a porosity; and a frame disposed about the periphery of the screen layers while substantially maintaining the porosity of the interior portion, the frame having fluid conduits disposed therein.

The electrochemical cell stack comprises: an electrolyte membrane having a first gas side and a second gas side; a first gas electrode disposed on the first gas side of the membrane; a second gas electrode disposed on the second gas side of the membrane; and an integral screen/frame assembly disposed adjacent to and in intimate contact with the first gas side, comprising: one or more screen layers having an interior portion with a porosity and having a periphery; and a frame disposed about the periphery of the screen layers while substantially maintaining the porosity of the interior portion, the frame having fluid conduits disposed therein.

The above discussed and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, which are meant to be illustrative, not limiting, and wherein like elements are numbered alike in the several FIGURES:

Figure 1 is a schematic diagram of a prior art electrochemical cell showing an electrochemical reaction.

Figure 2 is a cross sectional view of one embodiment of an electrochemical cell showing the relationship of the cell components.

Figure 3 is a plan view of one embodiment of a screen assembly of the present invention.

Figure 4 is a top view of another embodiment of the integrated frame 1 screen assembly of the present invention.

Figure 5 is an expanded side view of the integrated frame 1 screen assembly of Figure 4.

Figure 6 is an isometric view of one embodiment of a woven mesh of the present invention.

Figure 7 is an isometric view of one embodiment of a screen pack of the present invention employing a woven mesh.

The Figures are meant to further illustrate the present invention and not to limit the scope thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The screen/frame assembly of the present invention comprises multilayers of screens with layers of frame material disposed about the periphery, integral with the screen layer. Essentially, the frame forms a ring around and through the outer edge of the screen layers, bonding the layers together in an integral structure.

The screen layers can be any conventional screen configuration, with the configuration disclosed in commonly assigned U.S. Patent Application Serial No. 09/102,305, to Trent Molter et al., (Attorney Docket No. 97-1801) (hereby incorporated by reference) preferred. The screens should be electrically conductive and have a sufficient open area via perforations, openings between screen strands, or otherwise, to enable substantially unobstructed access of hydrogen, oxygen, and water to and/or from the electrodes. Possible screen materials can be electrically conductive materials, including, but not limited to, metal or metal-ceramic plates or stands in the form of perforated or porous sheets, or a woven mesh, such as niobium, nickel, cobalt, zirconium, titanium, steel (such as stainless), or tantalum, among others, and alloys thereof.

At least some of the screens are preferably planar layers having elongated openings, such as diamond or elliptical shapes, formed by strands. These openings can have a size of up to about 2/0 or greater. However, for operation at a pressure differential of about 400 p.s.i., it is preferred to employ small screen openings to prevent membrane blowout into the screen on the low pressure side of the membrane assembly. In one embodiment, a reduced opening size for at least the first screen layer is employed, with a reduced opening size employed for subsequent screen layers based upon mass flow demands. The actual size of the openings (perforations or holes) is dependent upon the desired mass flow rate and number of screen layers to be

employed. Referring to Figure 3, for a diamond pattern, in an electrolysis cell operating at a 390 psi pressure differential, a diamond size of less than 0.125 inches (3.17 mm) for dimension "b" (width), by less than 0.071 inches (1.80 mm) for dimension "a" is preferred. That is, about 3/0 to about 5/0 is preferred, and a 4/0 screen, which is about 0.077 inches (1.96 mm) by about 0.033 inches (0.838 mm) to about 0.046 inches (1.17 mm) is especially preferred for the screen layer adjacent the electrode. Subsequent layers can also employ small opening sizes or can have an opening size larger than the opening size of the screen layer adjacent the electrode to improve mass flow characteristics.

In another embodiment, one or more layers can be a woven mesh screen (see Figure 6). Although this mesh screen can be disposed anywhere within the screen pack, it is preferably disposed adjacent to and in intimate contact with the membrane and electrode assembly or the first screen layer. In this embodiment, the woven mesh screen provides structural integrity to the membrane. However, due to the hydrophobic nature of the mesh screen, an expanded screen having a relatively hydrophilic nature is preferably disposed between the woven mesh screen and the membrane.

The mesh size of the woven mesh screen is based upon the desired structural integrity requirements for the membrane and the desired gas production rate. For example, as the production pressure increases, the woven mesh size decreases to provide the desired structural integrity, and the current density (and therefore the production rate) is decreased to prevent membrane dehydration. Typically, the woven mesh screen can have a mesh size up to and exceeding about 200 mesh, with about 10 to about 110 mesh preferred, and about 20 to about 80 mesh especially preferred.

The preferred mesh size is determined based upon the relationship between the desired current density, production rate, production pressure, and issues of membrane dehydration. Since the woven mesh provides structural integrity to the membrane, as the production pressure increases, the mesh size preferably decreases (e.g. at a production pressure of about 50 p.s.i. the preferred mesh size is about 20 mesh, while at a production pressure of about 400 p.s.i. the preferred mesh size is about 80 mesh). As the mesh size decreases, however, the transfer characteristics of water to the membrane and oxygen from the membrane are restricted. Consequently, localized membrane dehydration can occur. To avoid membrane dehydration, it is typically preferred to

decrease the current density, thereby decreasing the production rate of oxygen and hydrogen. Therefore, the balance of the desired production rate and membrane structural integrity is weighed against the possibility of membrane dehydration.

Referring to Figure 7, in this embodiment the screen layer disposed between the woven mesh and the electrode has screen openings that are elongated, such as diamond or elliptical shaped. These openings can have a size of about 3/0 to about 5/0, with smaller openings especially preferred for higher pressure differential applications. The screen layer disposed between the woven mesh and the electrode has a thickness up to about 5 mil, with about a 3 mil thickness or less preferred. In contrast, subsequent screen layers (i.e. those disposed on the opposite side of the woven mesh) typically have screen openings up to or exceeding about 7/0, with about 3/0 to about 5/0 generally preferred, and about 4/0 especially preferred, and have a thickness up to about 7 mils or more, with a thickness of about 3 mil to about 5 mil generally employed.

The integral frame can be formed of any material that is compatible with the electrochemical cell environment, is capable of bonding the screen layers together, and preferably, is easily processed. Possible frame materials include, but are not limited to, thermosetting, thermoplastic, and rubber materials, such as polyetherimide, polysulfone, polyethersulfone, and polyarylether ketone (PEEK), Viton® (commercially available from E.I. duPont de Nemours and Company, Wilmington, DE), ethylenepropylenediene monomer, ethylenepropylene rubber, among others, and mixtures thereof, with thermoplastic materials preferred due to ease of manufacture. One example of a useful thermoplastic material is polyetherimide (e.g. Ultem® 1000 commercially available from General Electric Company, Pittsfield, MA).

Production of the screen/frame assembly can be any conventional manner of extruding the frame material into the screen layers accordingly, with actual processing conditions dependent upon the particular material employed. For example, Ultem® resin can be integrated with the screen layers by stacking the screen layers accordingly; placing an Ultem® resin ring above, below, and/or within the screen stack (70, 70'), and heating the stack under pressure to extrude the Ultem® resin through the stack, about the periphery of the screen layers (75, 75') (see Figure 5). In the alternative, multiple thin layers of Ultem® resin can be alternately stacked between the screen layers. Again

the stack is heated under pressure to force the Ultem® resin through the screens, thereby bonding them together to form an integral screen/frame assembly (see Figure 4).

Temperatures and pressures sufficient to extrude the frame through the periphery of the screen and bond the various layers of screen and frame together can be employed. Typically, with a thermoplastic material such as Ultem® resin, for example, temperatures of about 250°F to 500°F at pressures of about 10,000 to 20,000 pounds per square inch (psi) can be used, with temperatures of about 300°F to about 350° F at pressures of about 13,500 psi to about 16,000 psi preferred.

The frame material should have a sufficient overall thickness to enable bonding of all of the screen layers and to attain sufficient electrical contact between the screen layers and the membrane, while preferably not forming a ridge or other extension above the surface layers of the screens. Preferably, the overall frame thickness is approximately equal to the overall screen thickness to establish a uniformity between the frame and screen interface.

In a further preferred embodiment, the frame has the desired manifolds formed therein prior to assembling with the screens. In this embodiment, it is preferred not to over-heat the frame material. Preferably the material is only heated to a temperature which will enable extrusion into the screen, without allowing significant deformation or blockage of the manifolds. Once the extrusion process is complete, the integrated frame/screen assembly is preferably cooled slowly so as to reduce thermal stress. For example, the assembly is cooled from about 350°F to about 90°F or lower over a period of about 15 minutes or more.

Referring now to Figure 2, in operation, process water 2 enters inlet port 25 and a portion of the water is diverted into oxygen screen pack 43. A portion of the water 2 not diverted into screen pack 43, continues along conduit 25 formed by axially aligned holes in the components comprising the stack, and enters subsequent cells in the cell stack (not shown) positioned outside of the cell 1. The portion of process water 2 diverted through screen pack 43 contacts anode 3 where the water electrochemically converts to oxygen gas, protons, and electrons. Oxygen gas, as well as excess water, is exhausted from the cell through porting arrangements similar to those through which water is directed to the anode 3. The generation of gases in the cell, combined with external pressure regulation, produces a large pressure differential between the oxygen

7. A screen/frame integral assembly as in Claim 3, wherein at least a portion of said subsequent screen layers have second strands having a second thickness greater than said first thickness.

8. A screen/frame integral assembly as in Claim 7, wherein said first thickness is about half of said second thickness.

9. A screen/frame integral assembly as in Claim 1, wherein said screen layers have first openings which have a substantially elongated, diamond or oval shaped geometry.

10. A screen/frame integral assembly as in Claim 9, wherein said openings in one screen layer are disposed generally orthogonal to said openings in a subsequent screen layer.

11. A screen/frame integral assembly as in Claim 1, wherein frame is thermoplastic, thermosetting, or rubber materials, or mixtures thereof.

12. A screen/frame integral assembly as in Claim 11, wherein said frame is polyetherimide, polysulfone, polyethersulfone, polyarylether ketone, ethylenepropylenediene monomer, ethylenepropylene rubber, or mixtures thereof.

13. A screen/frame integral assembly as in Claim 1, wherein said screen layers comprise at least one woven layer.

14. A screen/frame intergral assembly as in Claim13, wherein said woven layer is disposed between and in intimate contact with two of said screen layers.

15. A screen/frame integral assembly as in Claim 13, wherein said woven layer has a mesh size down to about 300 mesh.

16. A screen/frame integral assembly as in Claim 15, wherein said woven layer has a mesh size down to about 200 mesh.

17. A screen/frame integral assembly as in Claim 16, wherein said woven layer has a mesh size of about 20 to about 80 mesh.

18. An electrochemical cell stack, comprising:

an electrolyte membrane having a first gas side and a second gas side;

a first gas electrode disposed on said first gas side of said membrane;

a second gas electrode disposed on said second gas side of said membrane; and

an integral screen/frame assembly disposed adjacent to and in intimate contact with said first gas electrode, comprising:

one or more screen layers having an interior portion with a porosity and having a periphery; and

a frame disposed about the periphery of said screen layers while substantially maintaining the porosity of said interior portion, said frame having fluid conduits disposed therein.

19. An electrochemical cell stack as in Claim 18, comprising at least two screen layers, wherein said frame bonds said screen layers together.

20. An electrochemical cell stack as in Claim 19, wherein:

said screen/frame assembly has a first screen layer having first openings having a first size of about 0.077 inches (1.96 mm) or less by about 0.033 inches (0.838 mm) or less and a first thickness of less than about 0.005 inches (0.127 mm) and at least one subsequent screen layer having subsequent openings, wherein said subsequent screen layer is disposed parallel to and in contact with said first screen layer and said first size and said first thickness are interrelated such that the combination of said first size and said first thickness enable the passage of water and the first gas through said first openings; and

a second gas screen assembly disposed adjacent to and in contact with said second gas electrode.

21. An electrochemical cell stack as in Claim 20, wherein the electrochemical cell has a pressure differential across said membrane such that a pressure at said first gas side of said membrane is lower than pressure at said second gas side of said membrane.

22. An electrochemical cell stack as in Claim 21, wherein said subsequent openings have a subsequent size and a subsequent thickness, wherein said first thickness is less than said subsequent thickness.

23. An electrochemical cell stack as in Claim 22, wherein said first thickness is about half of said second thickness or less.

24. An electrochemical cell stack as in Claim 20, wherein said first openings and said subsequent openings have a substantially elongated, diamond, or oval shaped geometry.

25. An electrochemical cell stack as in Claim 24, wherein said first openings are disposed generally orthogonal to said subsequent openings.

26. An electrochemical cell as in Claim 20, wherein said first thickness is about 0.0035 inches (0.089 mm) or less.

27. An electrochemical cell stack as in Claim 18, wherein frame is thermoplastic, thermosetting, or rubber materials, or mixtures thereof.

28. An electrochemical cell stack as in Claim 27, wherein said frame is polyetherimide, polysulfone, polyethersulfone, polyarylether ketone, ethylenepropylenediene monomer, ethylenepropylene rubber, or mixtures thereof.

29. An electrochemical cell as in Claim 18, wherein said screen layers comprise at least one woven mesh.

30. An electrochemical cell as in Claim29, wherein said woven mesh is disposed between and in intimate contact with two of said screen layers.

31. An electrochemical cell as in Claim 29, wherein said woven mesh is from about 20 to about 80 mesh.

32. An electrochemical cell as in Claim 27, wherein said screen/frame assembly is capable of providing structural integrity to said electrolyte membrane with a pressure differential across said electrolyte membrane of greater than 400 psi.

33. An electrochemical cell as is Claim 27, wherein the pressure differential across said electrolyte is greater than 1,000 psig.

34. An electrochemical cell screen assembly, comprising one or more screen layers comprising at least one woven layer and having an interior portion with a porosity.

35. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size down to about 300 mesh.

36. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size down to about 200 mesh.

37. An electrochemical cell screen assembly as in Claim 34, wherein said woven layer has a mesh size of about 20 to about 80 mesh.

38. A method for producing hydrogen, comprising:

a. introducing water to a first gas electrode in an electrochemical cell, said electrochemical cell comprising:

i. an electrolyte membrane disposed between the first gas electrode and a second gas electrode; and

ii. an integral screen/frame assembly disposed adjacent to and in intimate contact with said first gas electrode, comprising: one or more screen layers having an interior portion with a porosity and having a periphery; and a frame disposed about the periphery of said screen layers while substantially maintaining the porosity of said interior portion, said frame having fluid conduits disposed therein;

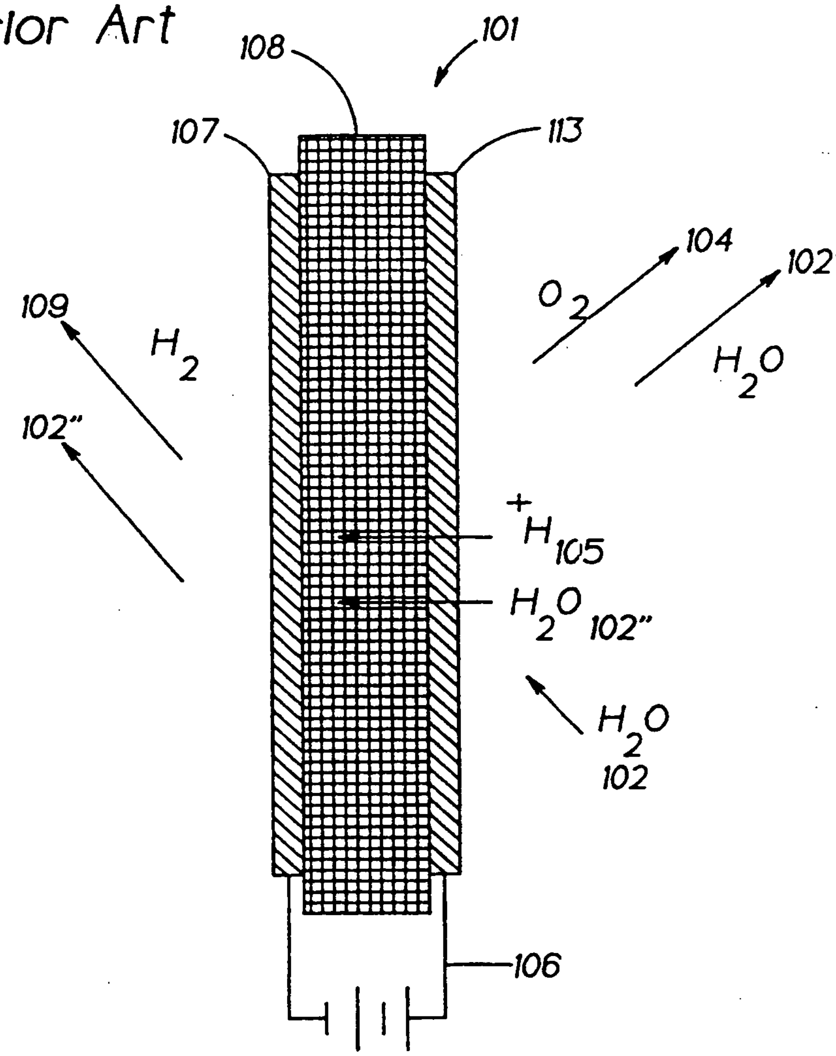
b. forming hydrogen ions, oxygen, and electrodes;

c. passing said hydrogen ions through said electrolyte membrane to said second gas electrode;

d. moving said electrons through an electrical load to said second gas electrode; and

e. combining said hydrogen ions and said electrons to form hydrogen gas.

FIG. 1
Prior Art



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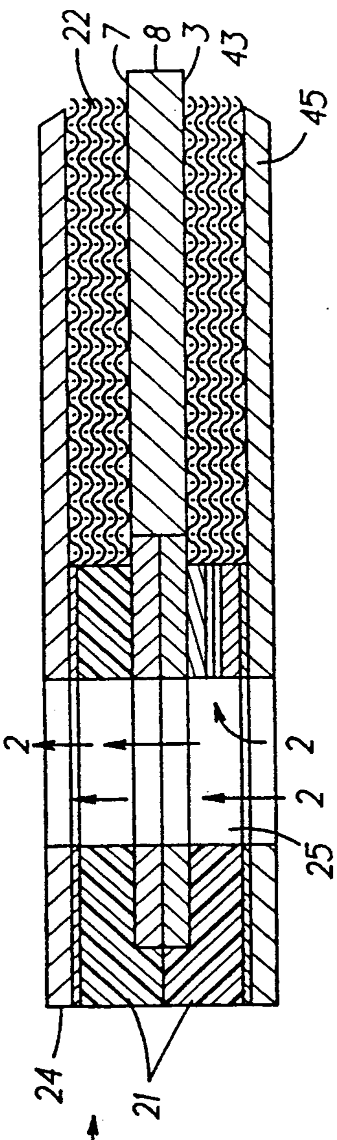


FIG. 2

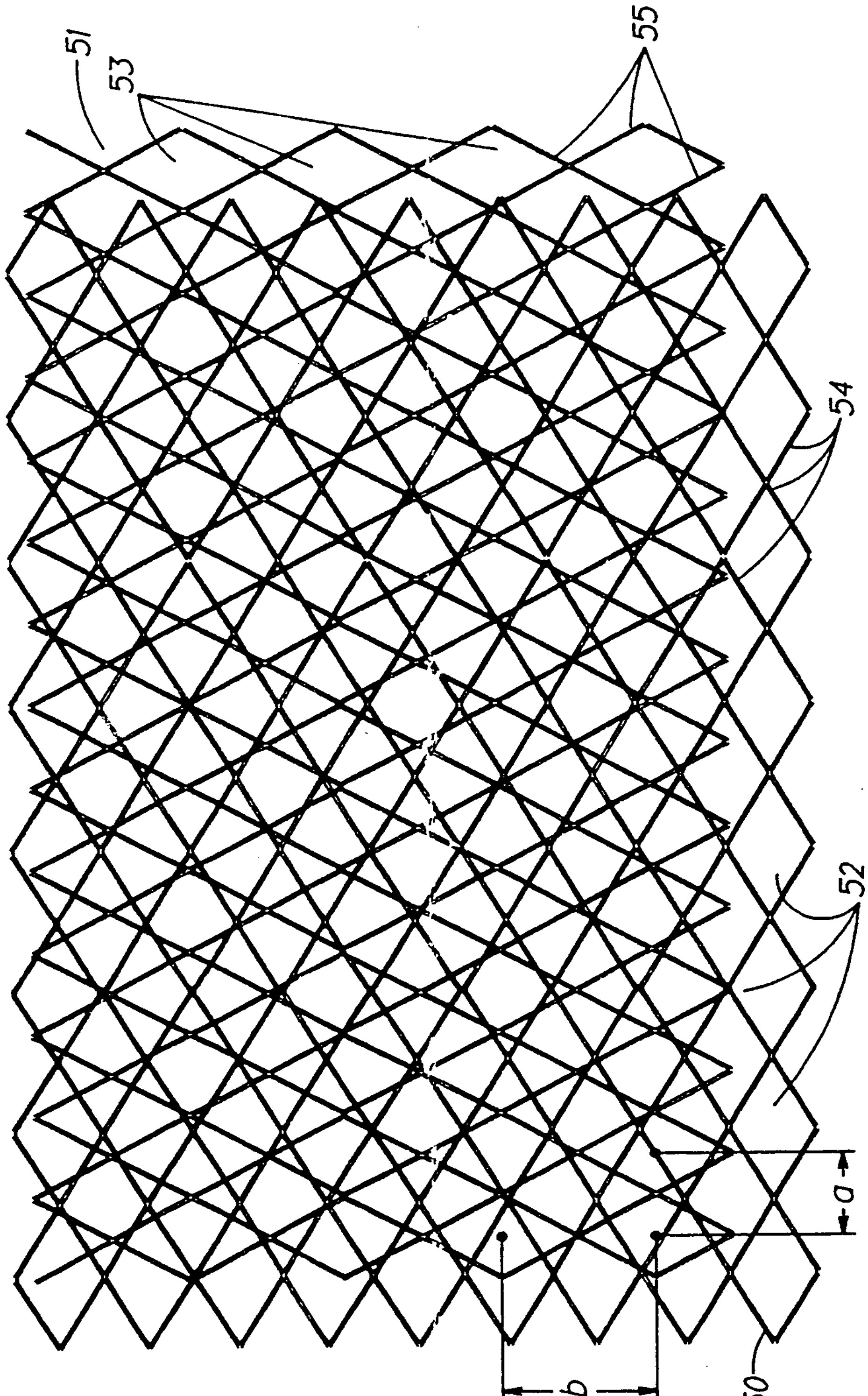
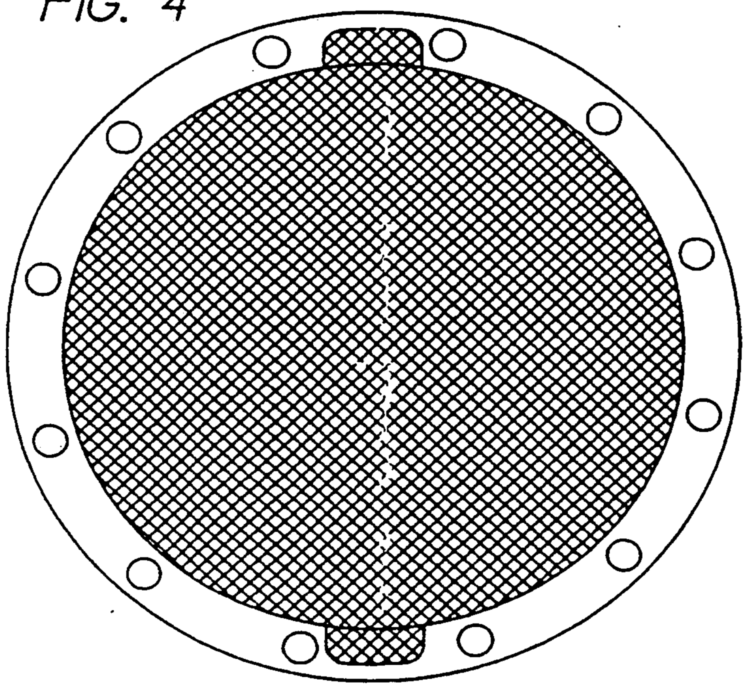


FIG. 3

FIG. 4



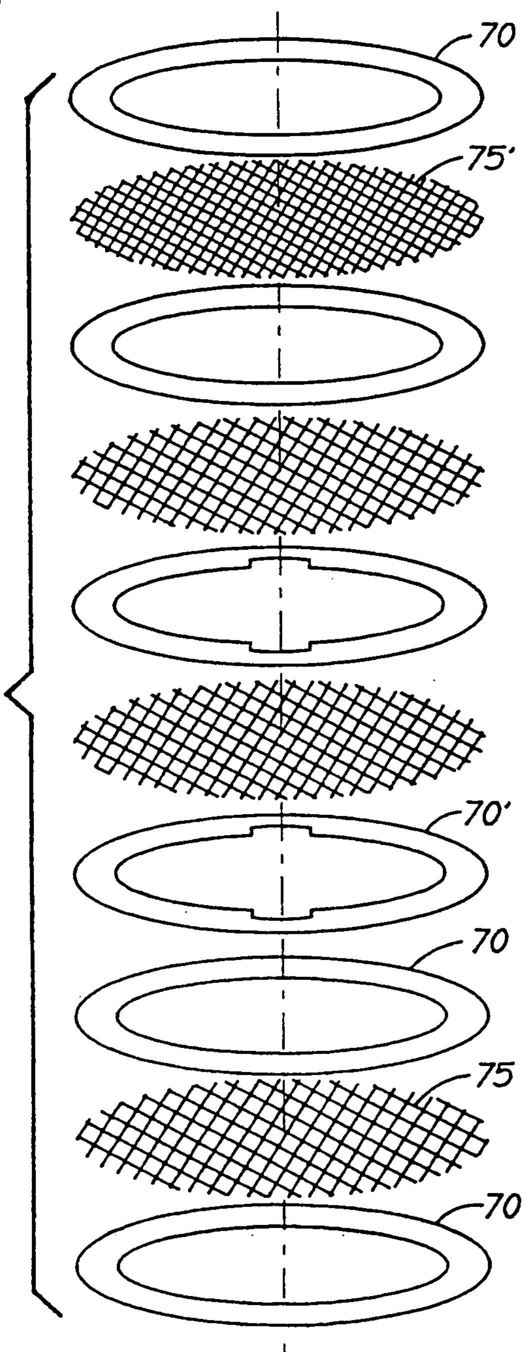


FIG. 5

FIG. 6

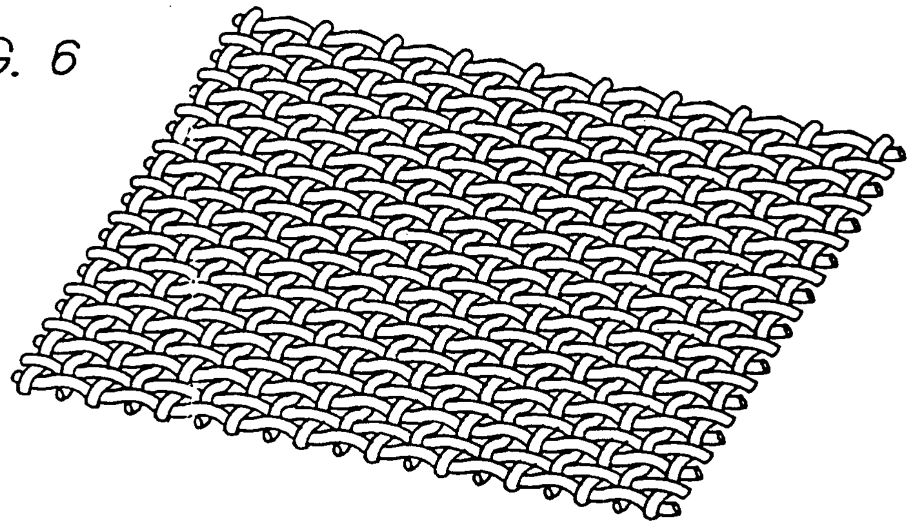
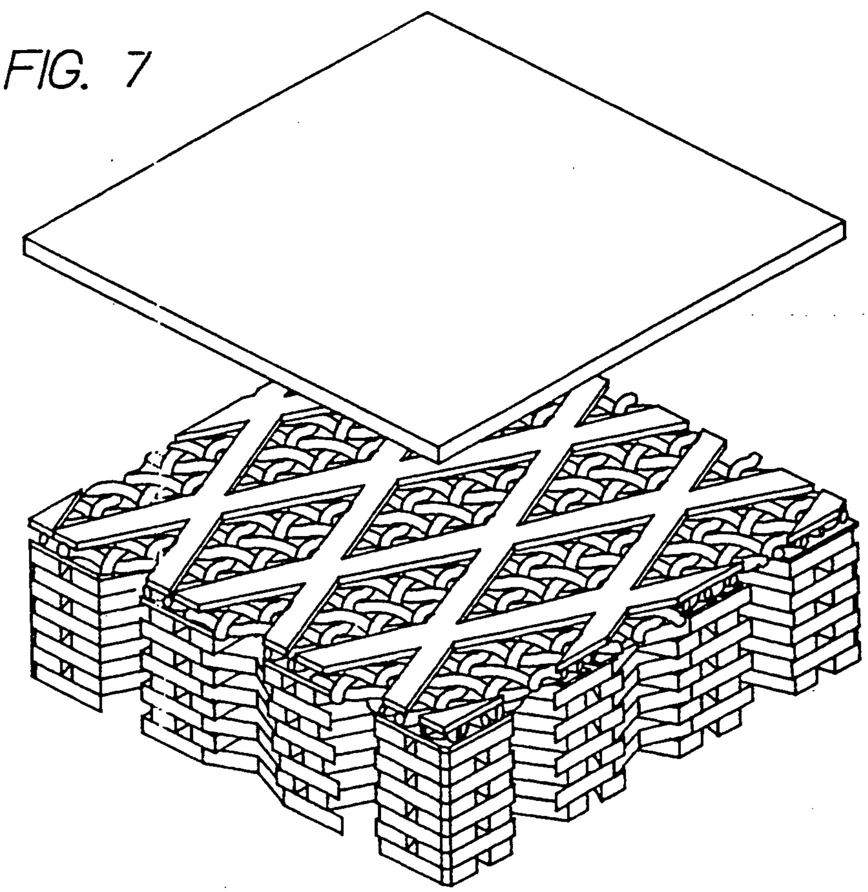


FIG. 7



INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/30085

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C25B9/00 C25B1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01M C25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 13891 A (ZAWODZINSKI CHRISTINE ;UNIV CALIFORNIA (US); WILSON MAHLON S (US)) 2 April 1998 (1998-04-02) page 5, line 9 - line 13 page 7, line 22 -page 8, line 11 page 9, line 27 -page 10, line 17 page 12, line 6 - line 19 page 14, line 1 - line 5 page 14, line 18 - line 21	1,2,6,7, 11,18, 19,22,27
A	figures 2,4	3

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Int. tional Application No
PCT/US 99/30085

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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